MEMS Technology for Jet Fuel Atomization

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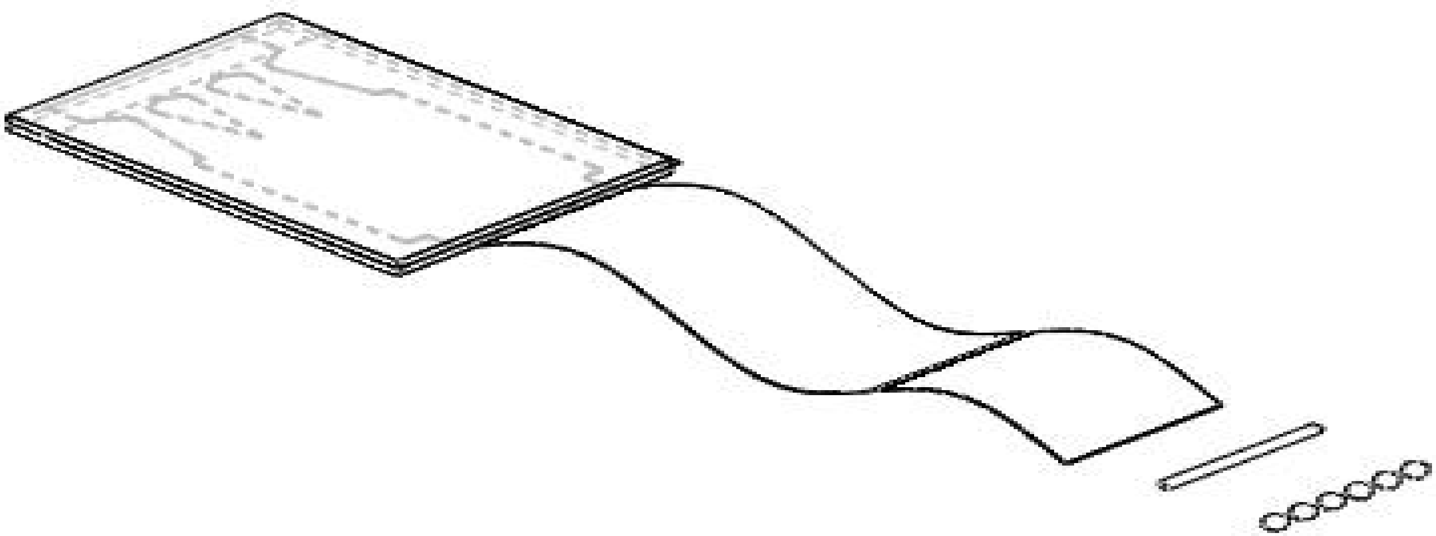
TDA Research, Inc



Turbine Engine Technology Symposium 2004
Fuel-Injector Technology Workshop
2 September 2004

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Report Documentation Page

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Outline

- Objective
- Atomizer technologies
- MEMS atomizer
- Approach to design, build and test
- Conclusions

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Objective

- Develop a MEMS atomizer to produce small (<50μm) droplets
  - improve gas turbine flameholding
  - reduce emissions

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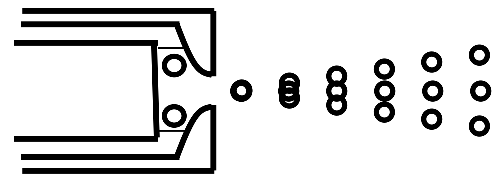
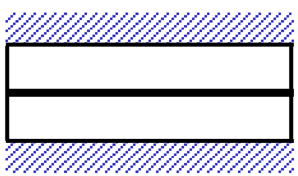
Baseline Technologies

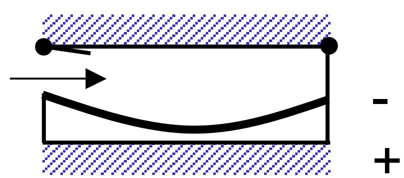
- Air blast / air assist (Many types; internal mixed type shown here)



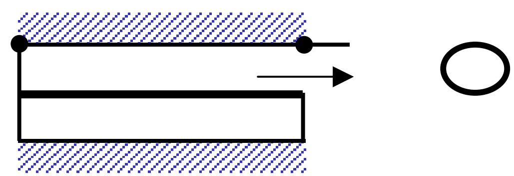
- Others: Simple Orifice, Poppet Orifice, Ultrasonic, Electrostatic Charge, **Inkjet**



Initial state



Applied DC voltage draws down the pressure plate or diaphragm



Remove voltage to release diaphragm and eject droplet

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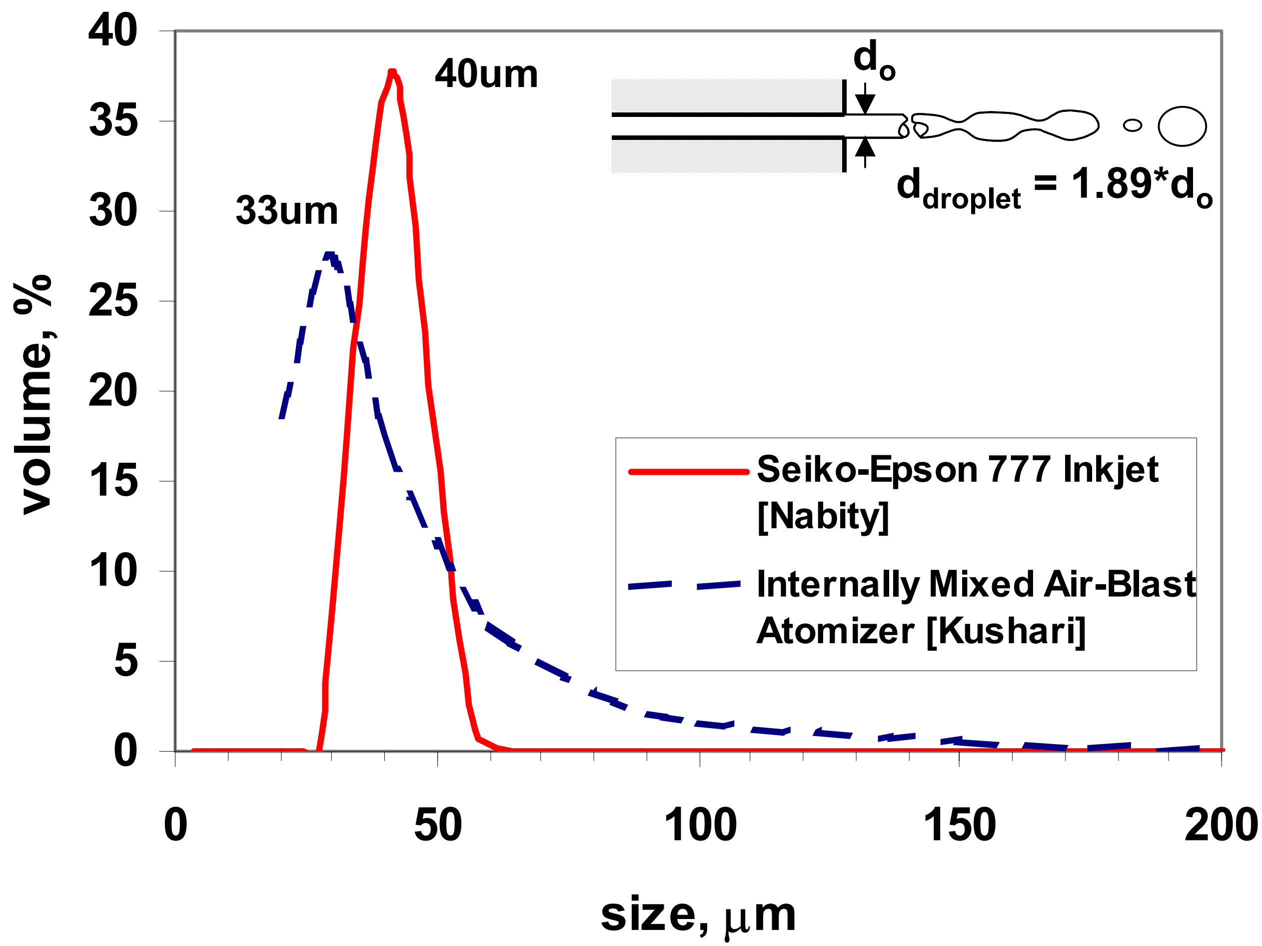
Droplet Size Measurements



A. Kushari, Y. Neumeier, O. Israeli, E. Lubarsky, and B.T. Zinn, "Internally Mixed Liquid Injector for Active Control of Atomization Process," Journal of Propulsion and Power, Vol. 17, No. 4, July-August 2001.

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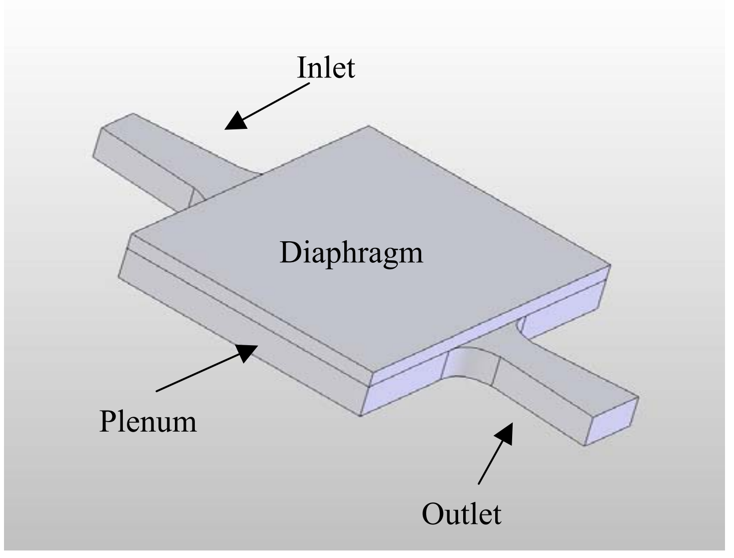
The Basic Design

- Electrostatically actuated diaphragm pump with passive valves:

  - Electrostatic for high displacement/low power.
  - Passive valves for simplicity.



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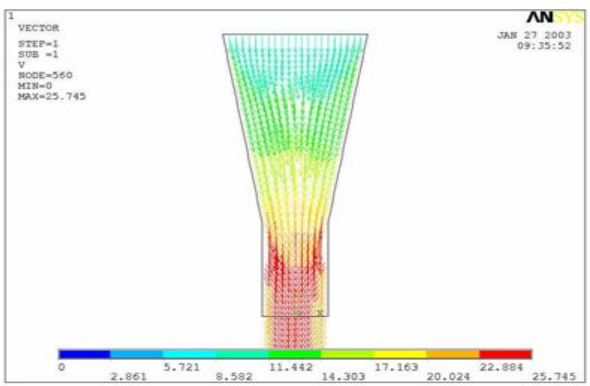
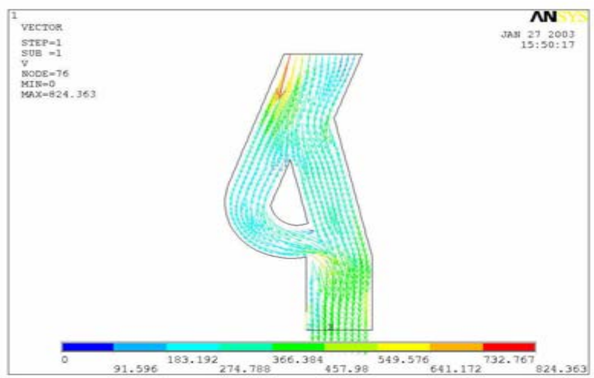
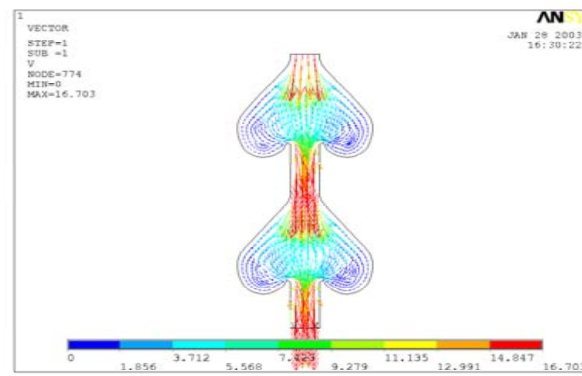
What is Important?

- Need high pump efficiency: $\eta = \dfrac{Q_{net}}{Q_{ideal}}$
- Valves are critical







- Dielectric – cleanliness is everything

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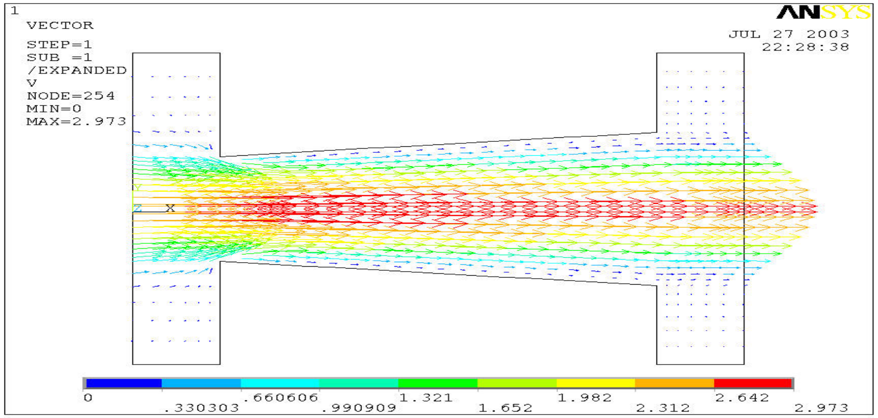
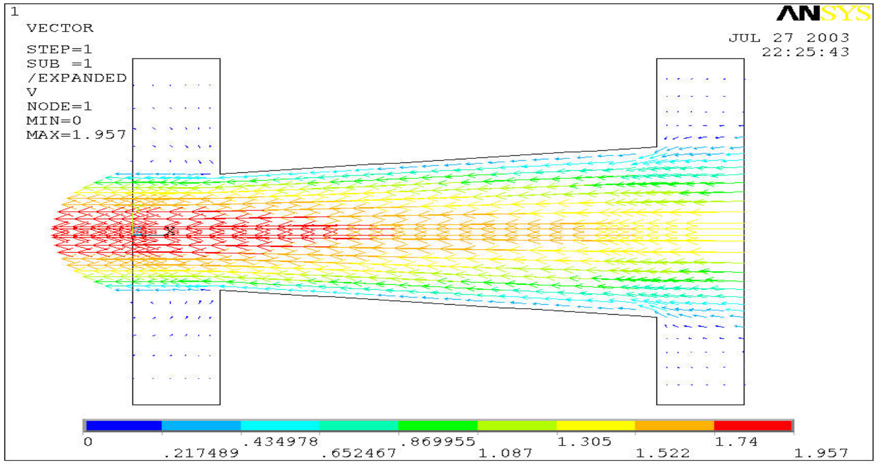
Approach

- Analytical & numerical performance modeling
  - Fuel ejection & droplet formation
  - Micropump operation (especially, the valving)
  - Stiction
- Fabrication
  - Materials, processes and assembly
- Engine integration
- Testing

Fluidic Valve Performance Evaluation



forward



reverse

	Flow rectification
Steady	2.2
Periodic	1.4

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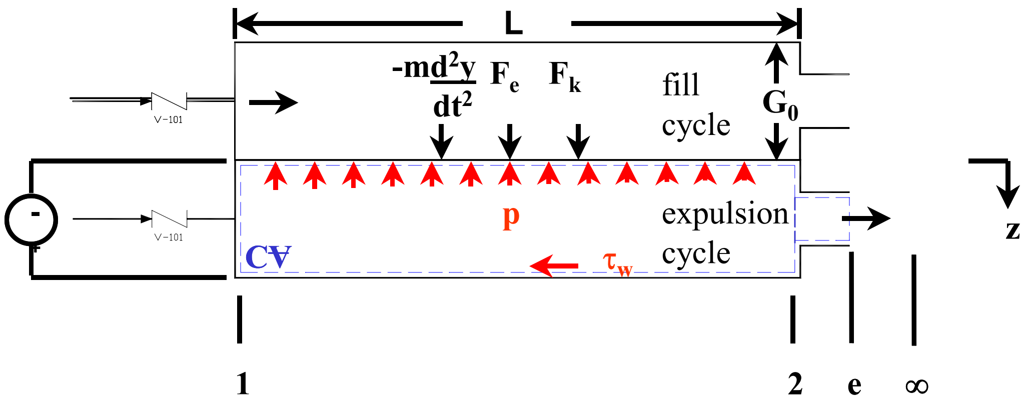
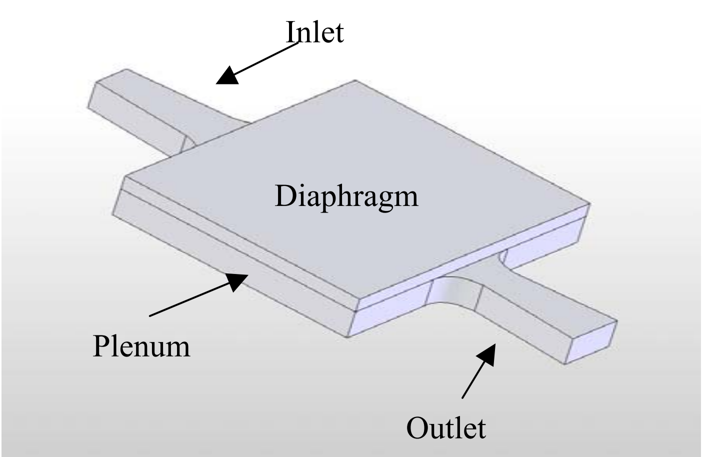
Performance Modeling

- TDA's Quasi 1-D Micropump Model



- ANSYS fully coupled modeling



$L_{diaph} = 1000\ \mu m$

$t_{diaph} = 10\ \mu m$

$t_{plenum} = 100\ \mu m$

$t_{passages} = 100\ \mu m$

$L_{passages} = 330\ \mu m$

$W_{inpassages} = 66.7\ \mu m$

$\alpha_{valve} = 5$ degrees

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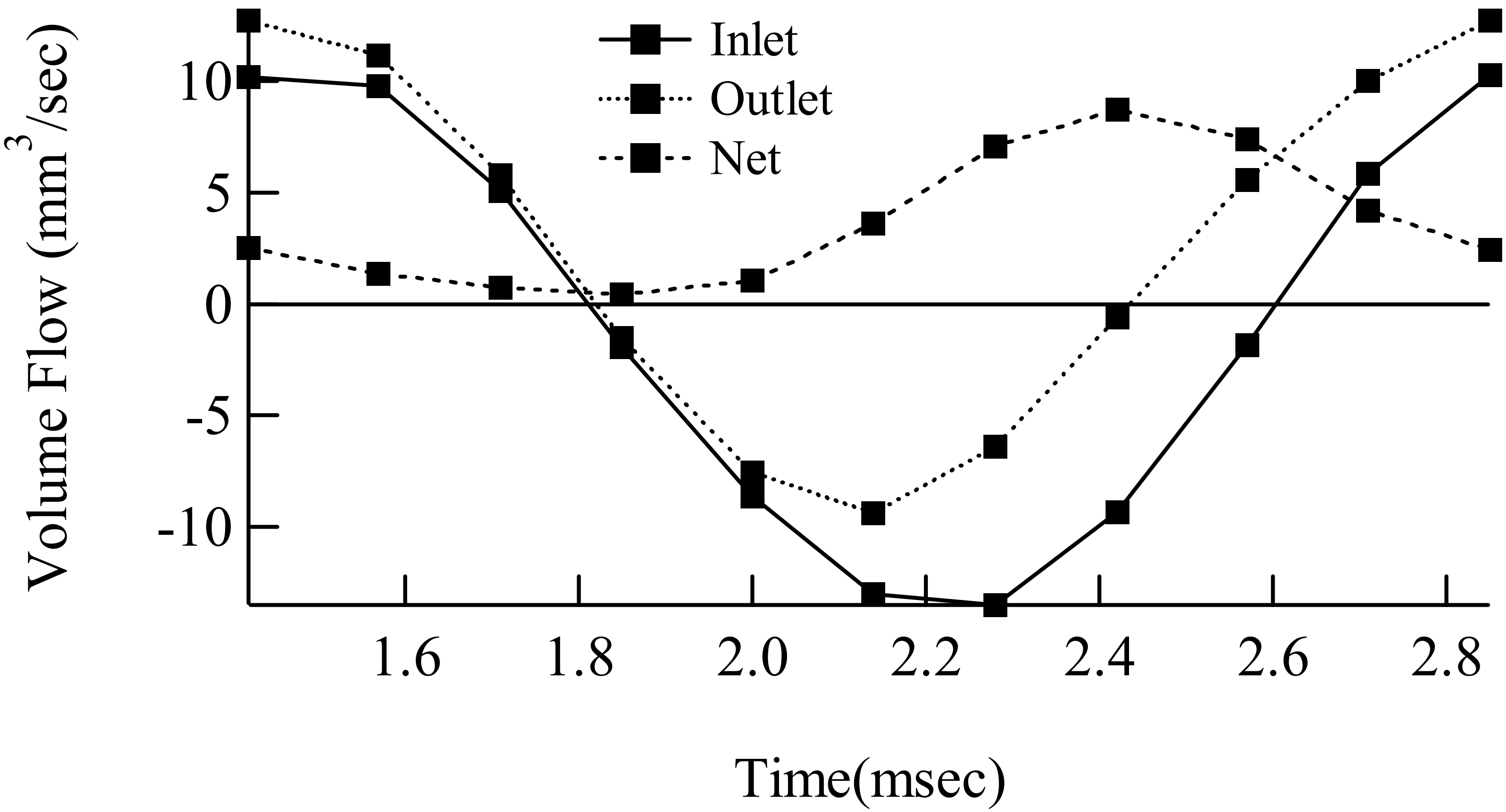
ANSYS Results
(30um sinusoidal deflection at 700 Hz)



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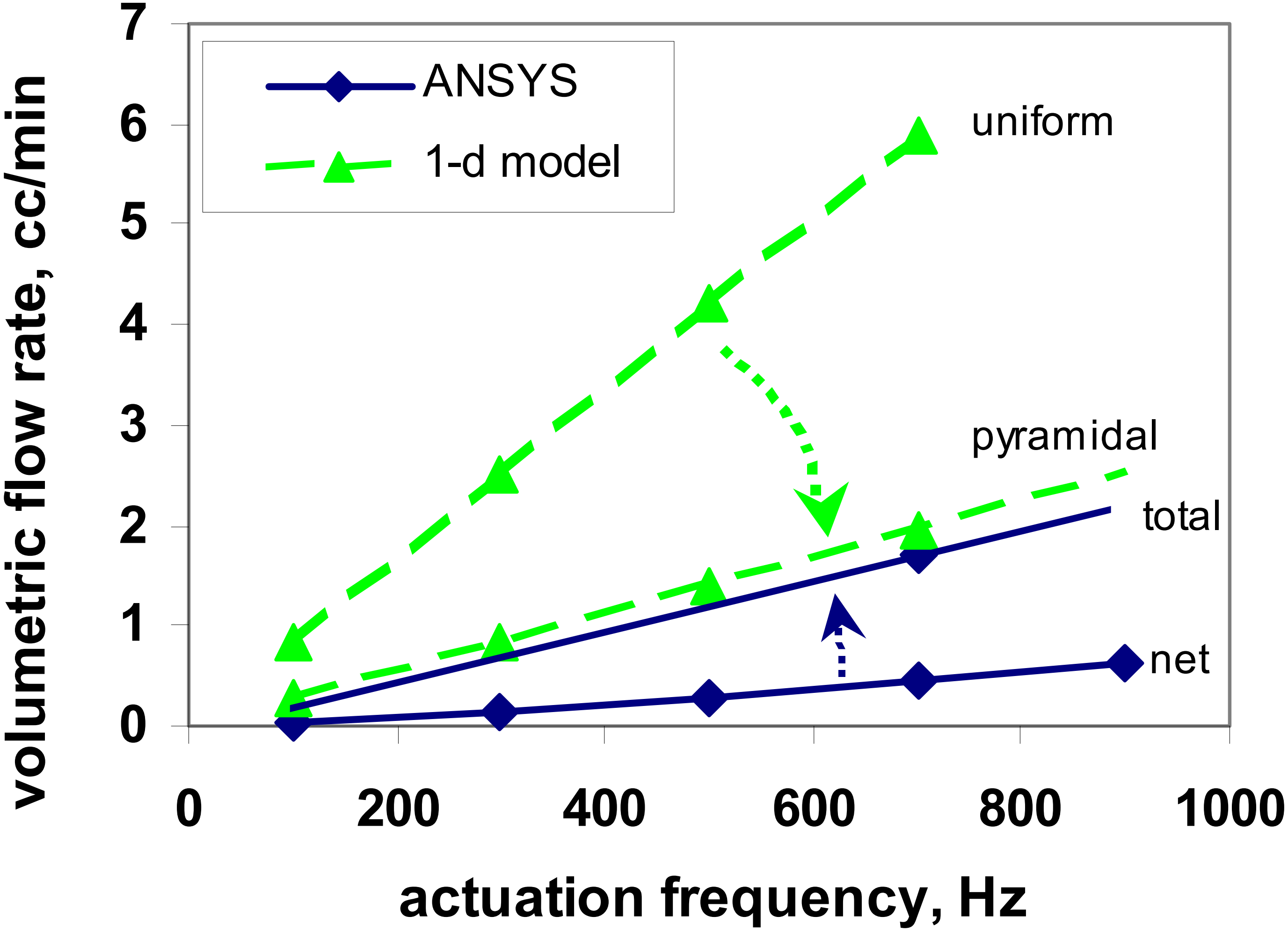
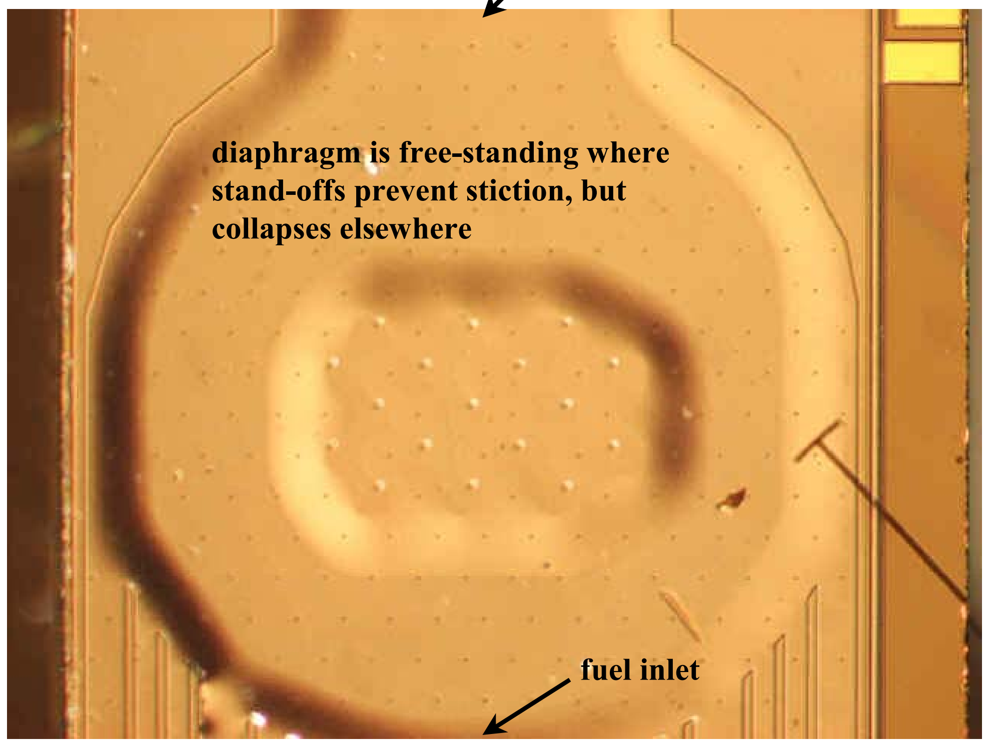
Model Performance Predictions



Stiction

- Nemesis to MEMS



- Therefore, use Mastrangelo elastocapillary & peel numbers

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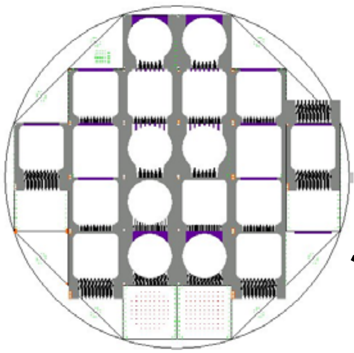
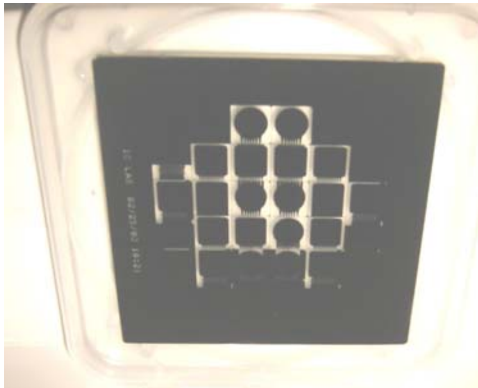
Materials

- Silicon – most commonly used material
  - 3-inch SSP wafer costs about $10
  - <1800°F
- Silicon carbide – 20X the cost, but good to 2900°F
- Silicon carbide nitride – also expensive, but highest temperature and strength

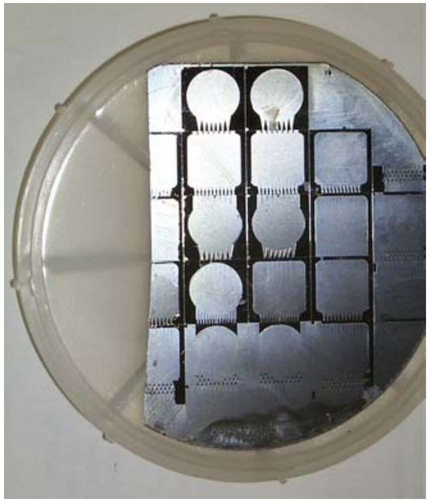
Wafer Level Microprocessing



CAD drawing



Mask



Pattern & etch

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Assembly & Packaging

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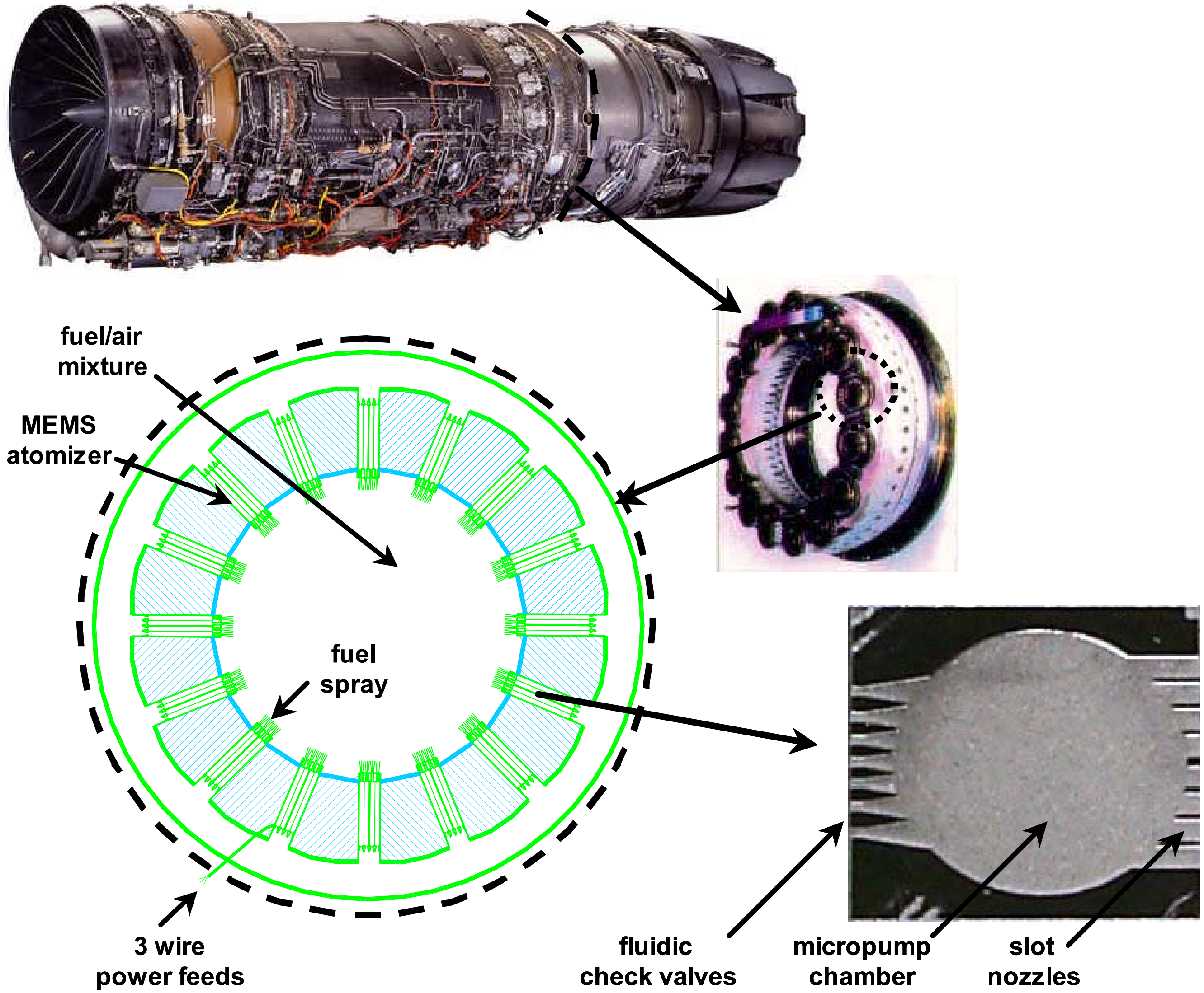
Gas Turbine



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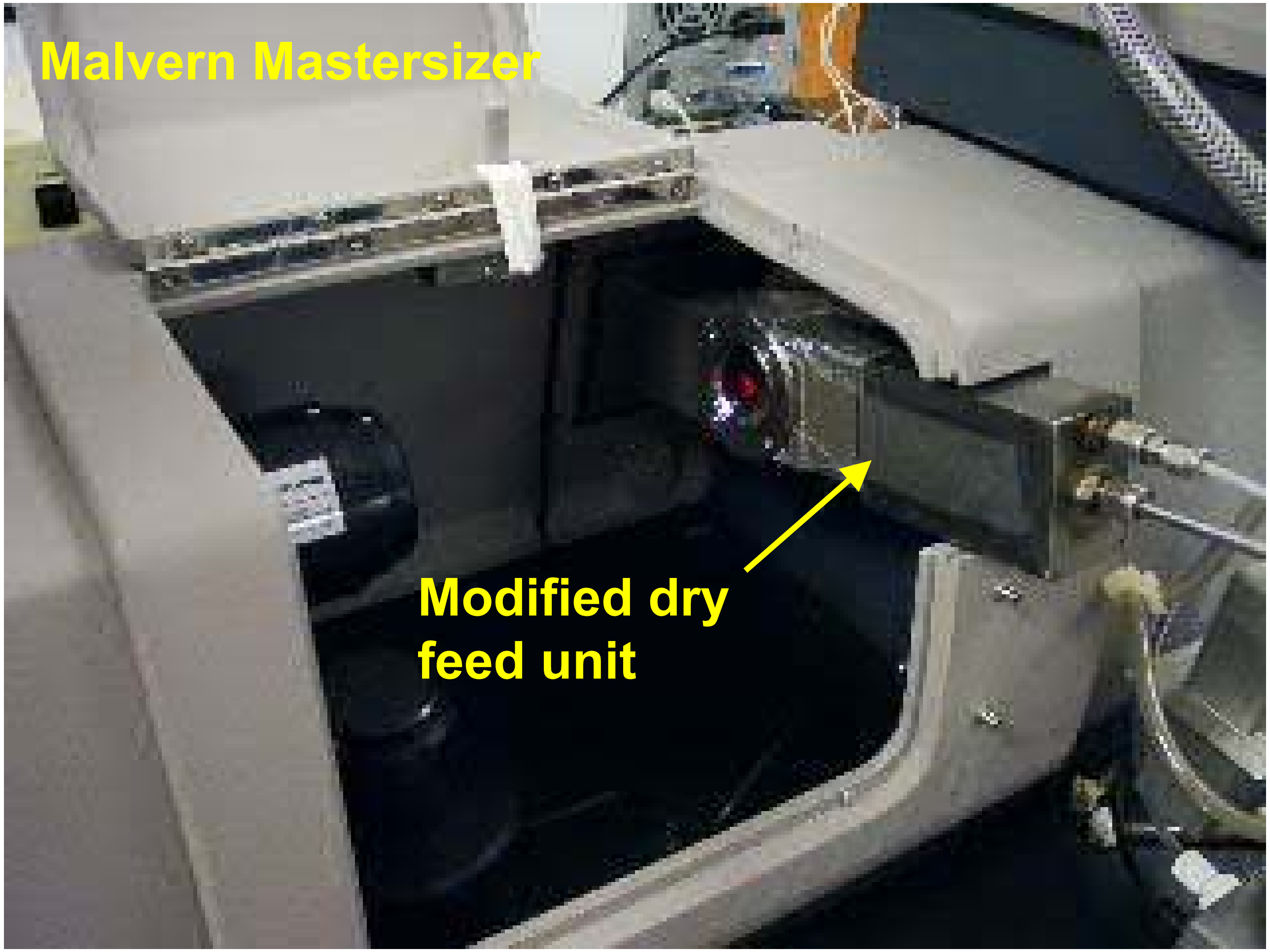
Test Setup



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Conclusions

- Analytical & computational tools Developed
- Design completed
- MEMS fabrication processes defined
- Atomizers built
- Testing underway

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